National Aeronautics and Space Administration

Fundamental Aeronautics Program

Subsonic Rotary Wing Project

Multi-Disciplinary Analysis and Technology Development (MDATD) - Overview

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2011 Technical Conference
March 15-17, 2011
Cleveland, OH

Multi-Disciplinary Analysis and Development

What are the objectives of MDATD in the Subsonic Rotary Wing project?

- Provide focal point for integrating discipline technologies and tools for system analysis
- Perform analysis and conceptual design of advanced rotorcraft systems and operations

How will the MDATD objectives be met?

- Develop, enhance, and integrate efficient design tools
- Conduct assessments of advanced technology for rotorcraft systems
- Study operations of advanced rotary wing configurations in NextGen

MDATD Highlights Since FY09

- Validated and demonstrated the NASA Design and Analysis of Rotorcraft (NDARC) sizing code
  - Written in FORTRAN. Runs on PC, Mac.
  - Released in May 2009
  - Distributed to 25 organizations (NASA, Army, Navy, Industry, Universities)

- Investigated concepts for Large Civil Tiltrotor 2 (LCTR2) engine-speed variation and drive system speed variation (Boeing, Rolls-Royce). First phase of study completed.

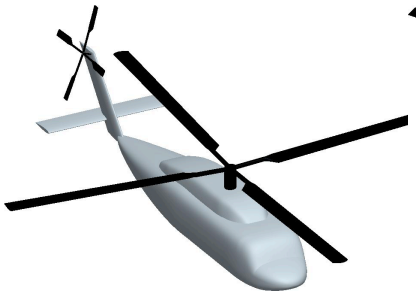
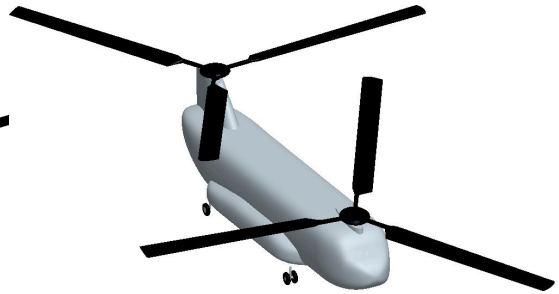
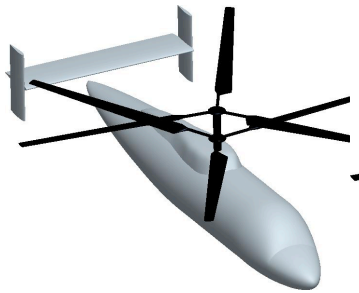
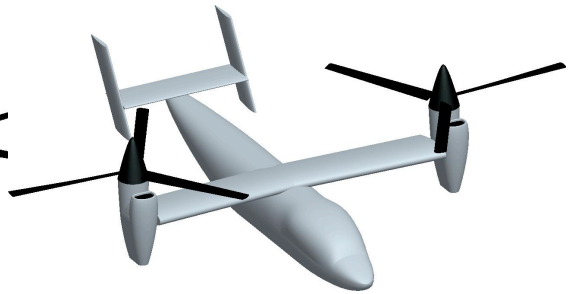
- Received SBIR Phase 2 deliverable, RotCFD, an Integrated Design Environment tool developed specifically for rotorcraft (Sukra Helitek, Inc.).

- Completed Year 2 of study “Modeling High-Speed Civil Tiltrotor Transports in the Next Generation Airspace” via a GSA contract (Team: SAIC (prime), Bell Helicopter, Sensis, Optimal Synthesis). Year 3 underway.

NDARC Validation

- Validated NDARC using test cases: UH-60A, CH-47D, XH-59A, and XV-15 rotorcraft
  - Developed NDARC models for each aircraft
  - Compared NDARC results for aircraft and component performance with flight test data

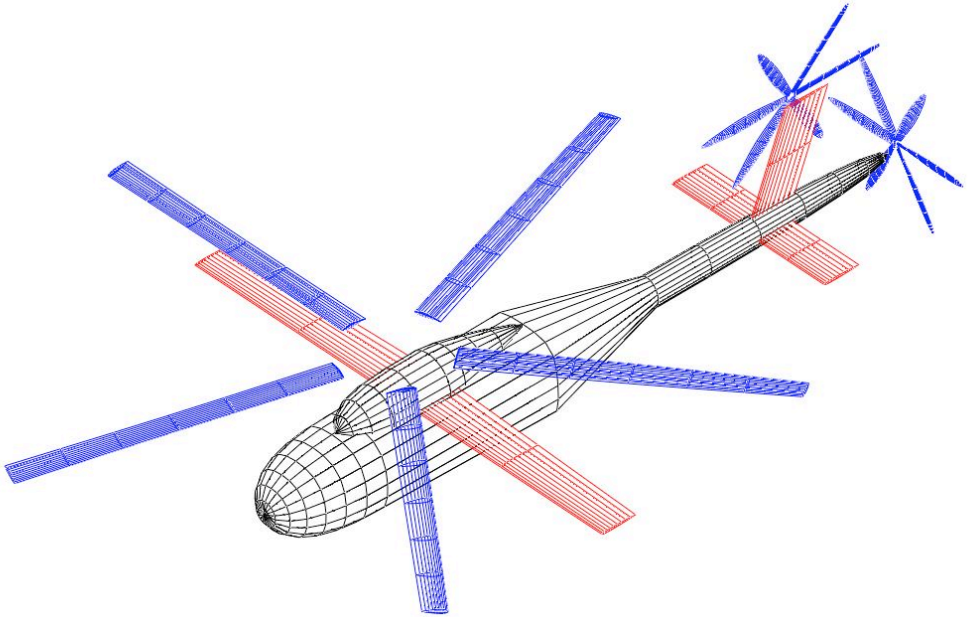


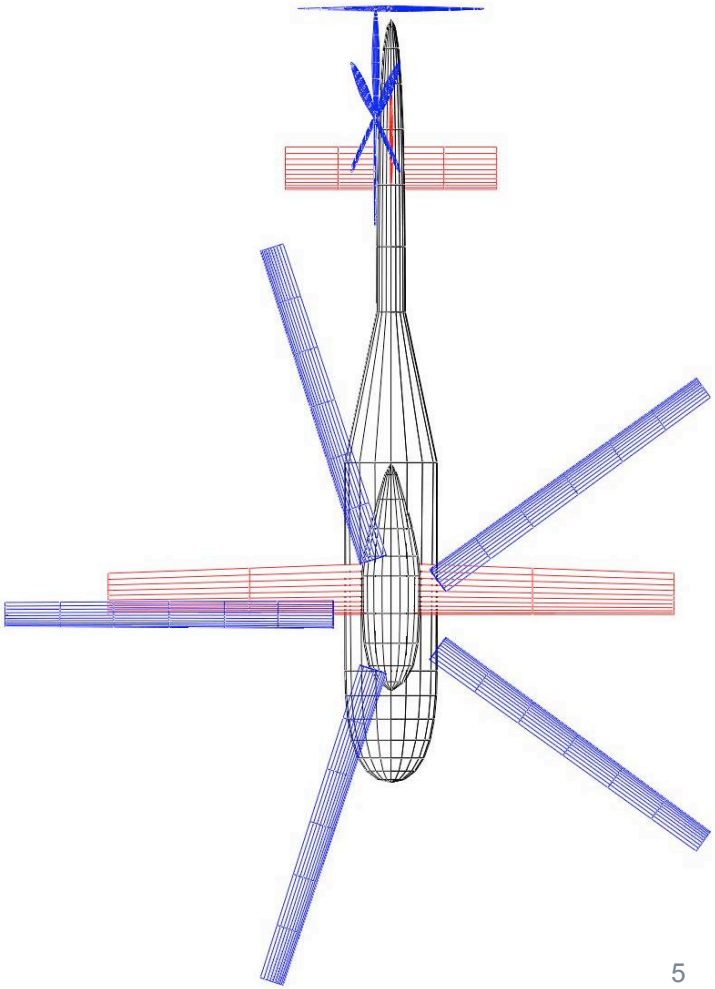






Figures from.: Johnson, W.: NDARC - NASA Design and Analysis of Rotorcraft, Validation and Demonstration. AHS Aeromechanics Specialists Conference, San Francisco, CA, January 2010.

NDARC Demonstration

- Synthesized and sized a slowed-rotor compound helicopter
- Investigated effects of main rotor tip speed and wing-rotor lift





Figures from: Silva. C., Yeo, H., and Johnson, W.: Design of a Slowed-Rotor Compound Helicopter for Future Joint Service Missions. AHS Aeromechanics Specialists Conference, San Francisco, CA, January 2010.

LCTR2 Engine Gearbox Study

Team: Boeing, Rolls-Royce, NASA

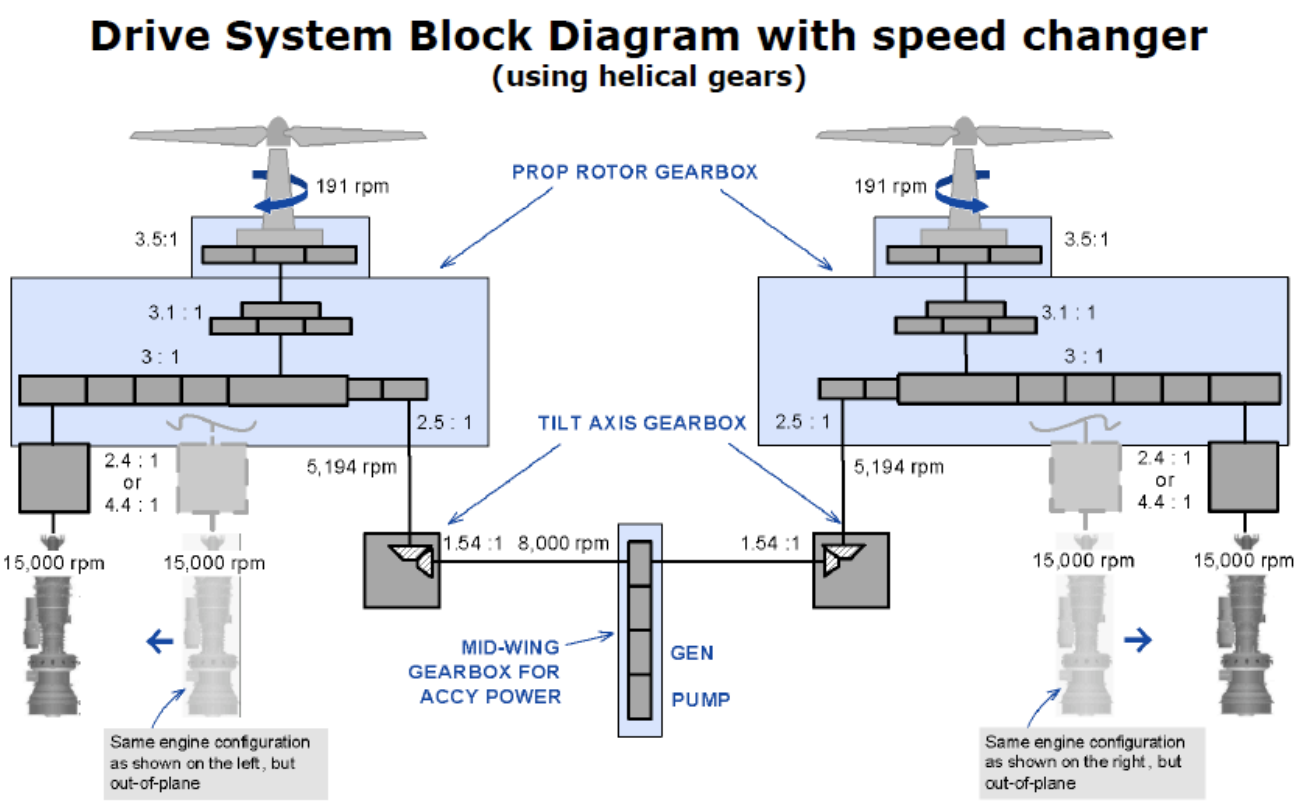
Objectives

- Validate benefit of reduced cruise tip speeds (350, 500, and 650 fps) for the LCTR2
- Assess trade-offs for reducing cruise rotor speed via the engine, 2-speed gearbox, or a combination of both
- Assess different engine cycles and advanced technology (COTS 2015, EIS 2025, EIS 2035) for improving power available at reduced engine RPM and to quantify the benefit of improved fuel flow

Summary

- 500 fps rotor tip speed (cruise) cases were generally optimum for vehicle gross weight and fuel burn
- For COTS 2015: optimum rotor cruise tip speed is probably near to or slightly less than 500 fps whether achieved through the engine or gearbox; other aircraft requirements must be considered for a more precise answer
- For EIS 2025: tailoring the engine performance at one RPM versus other RPMs is difficult, and must be carefully matched to the drive system and rotor performance components to be successful
- For EIS 2035: fixed-geometry variable-speed power turbine (VSPT) appears more promising (lower vehicle gross weight and fuel burn) than variable speed VSPT; more study is needed

Concept for LCTR2 Multi-Speed Drive System



To achieve multi-speeds, an individual speed changer is included with each engine (for redundancy / safety)

Figure from: Snyder, C. A., Robuck, M., Wilkerson, J., and Nordstrom, C.: Summary of the Large Civil TiltRotor (LCTR2) Engine Gearbox Study. American Helicopter Society International Powered Lift Conference, Philadelphia, PA, October 2010. NASA TM-2010-216908.

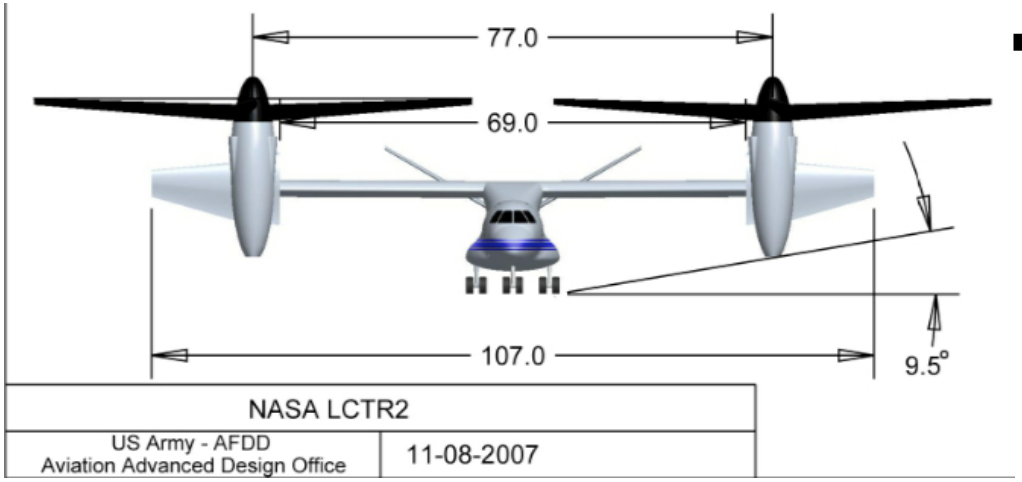
RotCFD – An Integrated Design Environment

Developed by Sukra Helitek, Inc. with funding from NASA SBIR

Features

- Currently runs on Windows XP
- GUI input and output menus
- Minimal CAD-like geometry engine to manipulate the body
- Automated hybrid grid generator
- Robust and economical incompressible flow solver for the entire system of grids
- Momentum source based rotor model
- Flow visualization tool for CFD post-processing

Enable Efficient Transition from a Conceptual Design to a CFD Solution



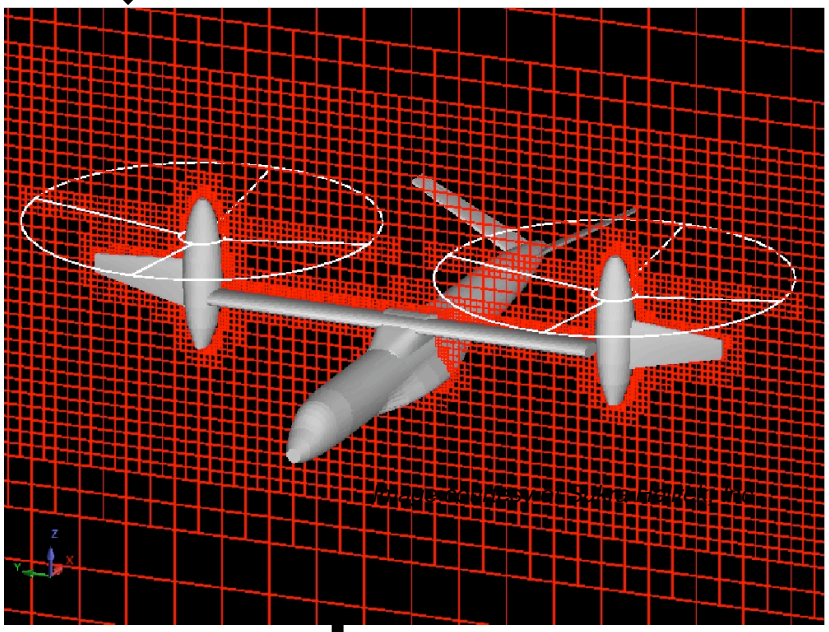


Image courtesy of Sukra Helitek, Inc

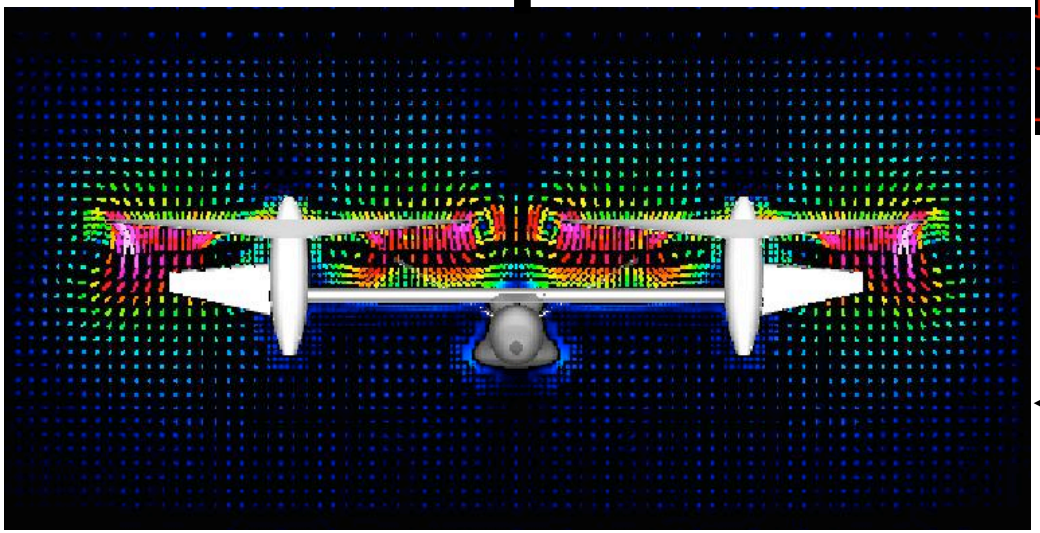


Image courtesy of Sukra Helitek, Inc

Plans

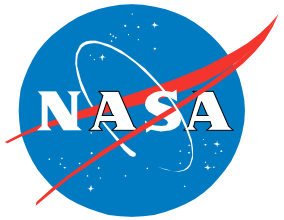
- Perform analysis of an advanced compound configuration using NDARC
- Refine LCTR2 variable speed gearbox system, dynamic modeling
- Further characterize LCTR2 variable-speed power turbine
- Compile library of configurations and components to analyze using RotCFD
  - LCTR2
  - single main rotor helicopter
  - tandem
  - coaxial
  - compounds
- Complete Year 3 of the study “Modeling High-Speed Civil Tiltrotor Transports in the Next Generation Airspace.” Focus will be on a disaster relief scenario.

Publications since FY09

- Acree, C. W.: Integration of Rotor Aerodynamic Optimization with the Conceptual Design of a Large Civili Tiltrotor. AHS Aeromechanics Specialists Conference, San Francisco, CA, January 2010.
- Acree, C. W.: Impact of Aerodynamics and Structures Technology on Heavy Lift Tiltrotors. January 2010 issue of the AHS Journal, Vol. 55, No. 1
- Datta, A. and Johnson, W.: "A Multibody Formulation For Three Dimensional Brick Finite Element Based Parallel and Scalable Rotor Dynamic Analysis. American Helicopter Society 66th Annual Forum, Phoenix, AZ, May 2010.
- Johnson, W.: NDARC - NASA Design and Analysis of Rotorcraft, Theoretical Basis and Architecture. AHS Aeromechanics Specialists Conference, San Francisco, CA, January 2010.
- Johnson, W.: NDARC - NASA Design and Analysis of Rotorcraft, Validation and Demonstration. AHS Aeromechanics Specialists Conference, San Francisco, CA, January 2010.
- Silva. C., Yeo, H., and Johnson, W.: Design of a Slowed-Rotor Compound Helicopter for Future Joint Service Missions. AHS Aeromechanics Specialists Conference, San Francisco, CA, January 2010.
- Snyder, C. A.: Effects of gas turbine component performance on engine and rotary wing vehicle size and performance. American Helicopter Society 66th Annual Forum, Phoenix, AZ, May 2010.
- Snyder, C. A., Robuck, M., Wilkerson, J., and Nordstrom, C.: Summary of the Large Civil TiltRotor (LCTR2) Engine Gearbox Study. American Helicopter Society International Powered Lift Conference, Philadelphia, PA, October 2010. NASA TM-2010-216908.
- Young, L., Chung, W., Paris, A., Salvano, D., Young, R., Gao, H., Wright, K., Miller, D., and Cheng, V.: A Study of Civil Tiltrotor Aircraft in NextGen Airspace. AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Ft. Worth, TX, September 2010.

Future Publications

- Robuck, M., Wilkerson, J., Zhang, Y., Snyder, C. A., and Vonderwell, D.: Design Study of Propulsion and Drive Systems for the Large Civil TiltRotor (LCTR2) Rotorcraft. American Helicopter Society 67th Annual Forum, Virginia Beach, VA, May 2011.
- Snyder, C. A.: Defining gas turbine engine performance requirements for the Large Civil TiltRotor (LCTR2). American Helicopter Society 67th Annual Forum, Virginia Beach, VA, May 2011.
- Abstract submitted: Young, L., Chung, W., Paris, A., Salvano, D., Young, R., Gao, H., Wright, K., and Cheng, V.: Civil Tiltrotor Aircraft Operations. 11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Virginia Beach, VA, September 2011.


NASA